Vortical Sea-Surface Features Generated by a Submerged Body in a Current Field

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LONG-TERM GOAL

The long-term goal is to contribute to our understanding of sea-surface roughness as influenced by various air-sea interacting processes. In particular, we are interested in identifying the sea-surface features generated by submerged bodies under various environmental conditions.

OBJECTIVES

Scientific objectives are aimed to quantify the modification of sea-surface roughness by a submerged body under various wind and current conditions, and to establish a proper algorithm to identify associated vortical surface features. It is anticipated that the results will be beneficial to shallow water mine detection with remote sensors.

APPROACH

Extensive laboratory experiments will be performed at our Wind-Wave-Current Research Facility (WWCRF) under various controlled wind and current conditions. Spheres of various diameters will be placed separately at several depths. The sea-surface undulations will first be recorded on video tapes, then a two-dimensional scanning laser slope gauge (SLSG) will be deployed to map the spatial and temporal features of the surface. The video images will be processed to provide general characteristics of eddies, such as the frequency of occurrence, the location of first apperance, and the propagation speed. On the other hand, the SLSG data will be processed to provide quantitative descriptions of these features in both spatial and temporal domains. Furthermore, the observed surface features will be compared with the turbulence structure of aqueous flow; the latter will be measured with our hot-film anemometer (TSI IFA-300). To substantiate our efforts, either radar or IR measurements will be conducted jointly by our collaborators from Naval Research Laboratory (NRL); laboratory results will be documented for modeling effort.

WORK COMPLETED

Video imaging: Sea-surface images under various experimental conditions were recorded on a CCD tapes. The general characteristics of vortical features were derived.

SLSG efforts: A series of experiments were conducted. The spatial and temporal features of vortical features were sucessfully derived from our SLSG measurements. Partial results were compiled and documented. We have nearly finished processing the remaining data.

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Aqueous flow: We have completed the acquisition and installaton of the hot-film annnometry system for the proposed turbulence measurements in the aqueous flow, These measurements are in progress.

RESULTS

The vortical features were clearly shown in CCD images. The appearance of these features was found to be dependent of Froude and Reynolds numbers. The generation of seconday vortices, however, remains to be verified with aqueous flow measurements. The eddies' appearence is accompanied by the disruption of thermal boundary, the associated temperature rise is also shown in the IR images in a separate experment at WWCRF by Smith et al. (1997).

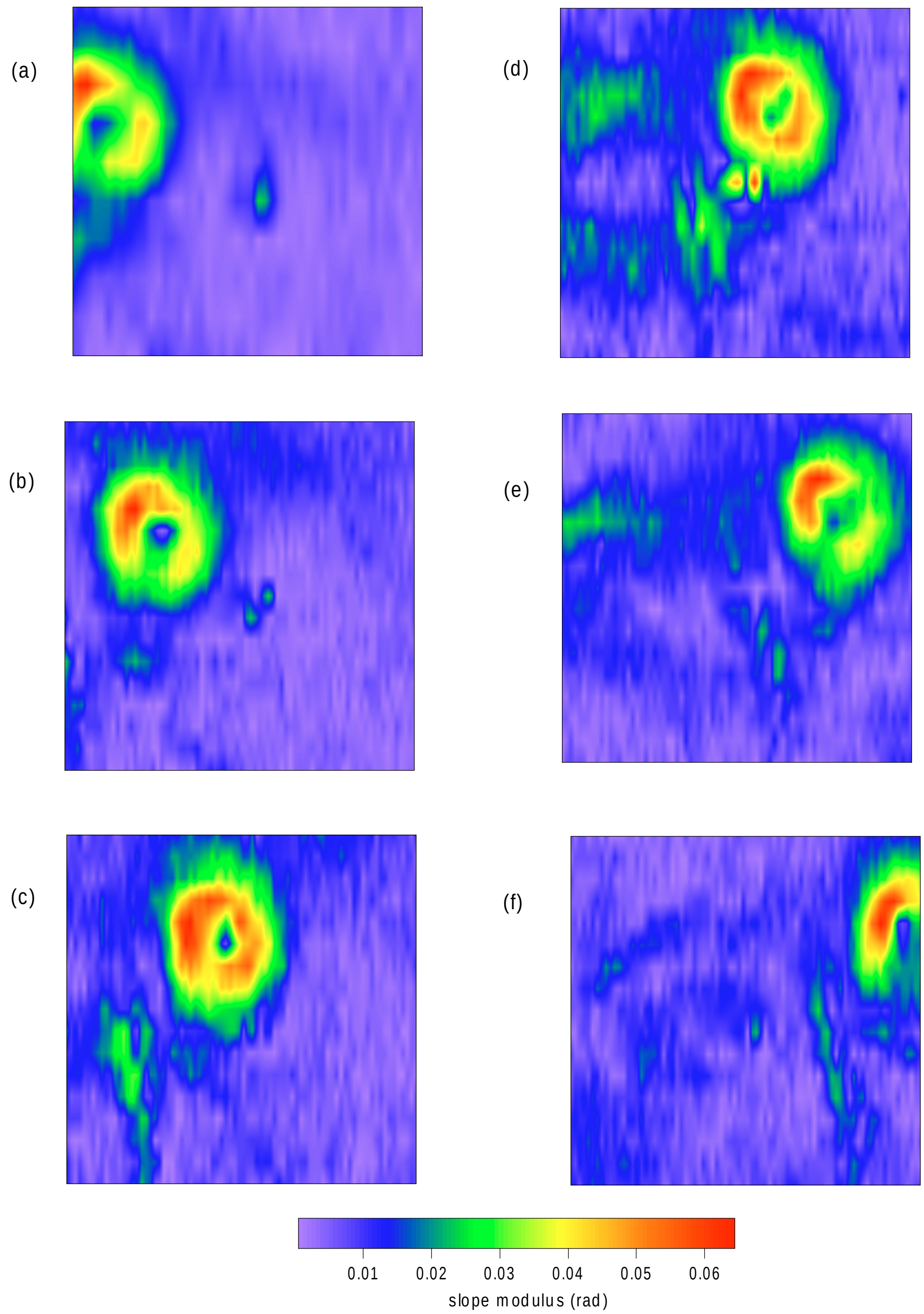

Figure 1. Slope mappings as eddies pass SLSG's window. The time gap between two adjacent images is 51 ms; the physical size of these images is 8 cm x 8 cm.

Detailed spatial and temporal features were clearly mapped with our SLSG. As an example, the passage of an eddy through the SLSG's 8 cm × 8 cm window at the time step of 51 ms is shown in Figure 1; the color bar indicates the slope values. The vortical eddy features are propagating from left to the right at the speed about 20 cm s^{-1}; quite steep slopes associated with these eddies are observed. The dimples associated with these features shown in the figure are in centi- to milli-meter scales.

These fine-scale variations may contribute to a subtle influence on radar sea returns. Note that the vortical feature is three dimensional, this is indicated by the equal slope components as vortices appeared in the SLSG's footprint, as shown in Figure 2. It is obvious that Figure 2 indicates that slope mapping is adequate in indentifying the vortical features.

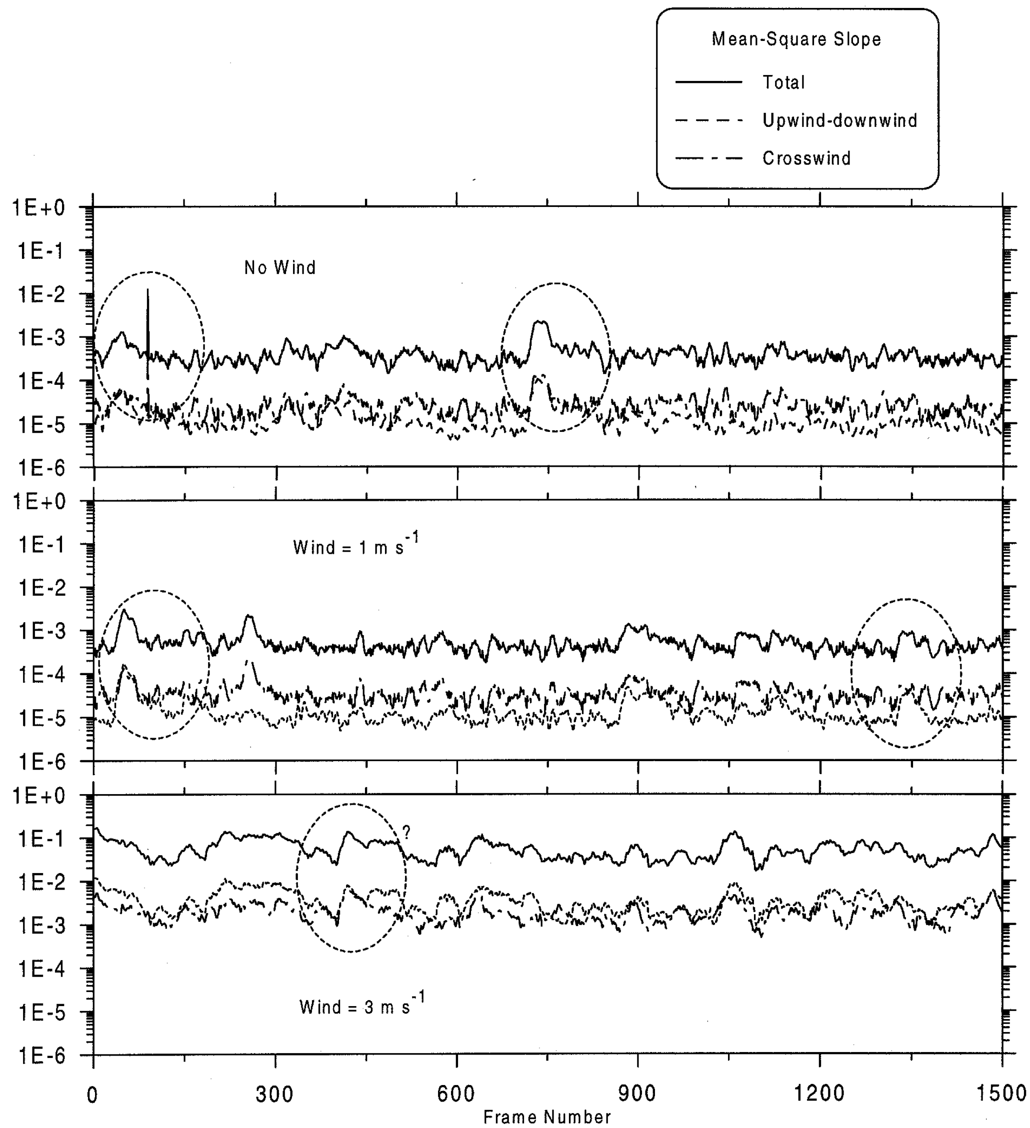

Figure 2 - Mean-square slopes at each frame. Surface slopes are evenly distributed as eddies appeared (dotted circles).

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IMPACT/APPLICATION

These surface features offer a quite unique opportunity for detection of nearshore mines with remote sensors. For example, the imaging radar, which receives signals of the sea-surface feature, is a potential candidate for such operations. Our effort in characterizing these features under various environmental conditions will certainly lead to a proper algorithms for mine detection.

TRANSITIONS

Detailed current profiles at various sections along the tank were made available for modeling effort at NRL. Our experimental setup was also used for IR measurements.

RELATED PROJECTS

The features derived from our CCD and SLSG measurements were compared with the thermal signatures obtained from a separate experiment with an IR camera by Geofreey Smith (NRL) and Richard Leighton (NRL).

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PUBLICATIONS

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